Accounting for Risk - Methods and Examples

Risk Assessment Methods

Although it is impossible to account for all uncertainties and risks in a planning study, their existence can be acknowledged and techniques can be used to assign quantitative importance to them in the analysis. These techniques include direct enumeration, sensitivity analysis, scenario analysis, probability analysis, game theory, robust decision methods, and stochastic simulation. Planners may combine analyses, such as performing scenario analysis supported by probability analysis.

- **Direct enumeration.** With this technique, all possible outcomes of the future event are listed. Although this would provide decision-makers an idea of the possible outcomes of an action, it does not provide any clue to the probability of one event happening over another. Also, given the complex relationships that are involved in most water resource studies, all possible outcomes are not likely to be known.
- **Sensitivity analysis.** In sensitivity analysis, the values of important factors contributing to the outcomes can be varied to test their effects upon the system being analyzed. These factors can be tested one at a time to find ones that have a significant impact on the outcomes and those that do not. An example of this would be to vary the assumption about future energy costs. If different energy costs do not have a significant effect upon the relative ranking of the proposed project relative to its alternatives, the analyst may feel more comfortable with the project. Although sensitivity analysis is relatively easy to do, it has drawbacks: (a) it frequently assumes that the appropriate range of values is known and that all values are equally likely to occur and (b) the results of the analysis are often reported as a single, most likely value that is considered precise.
- **Scenario analysis.** Scenario analysis is similar to sensitivity analysis except groups of factors are tested to together in a methodical way. Each scenario includes factors that support a given theme or story. For example, one scenario could include factors that imply high growth in demand for water and another could include factors that support low growth in demand for water. In this way, scenarios can be compared. The Water Plan uses scenarios to consider possible future conditions combined with Robust Decision Making described below in the analysis of future water management vulnerabilities and evaluation of alternative resource management strategies.
- **Probability analysis.** Although it is recognized that the “true” values of planning and design variables and parameters are not known with certainty and can take on a range of values, it may be possible to describe a variable or parameter in terms of a probability distribution. For example, for a normally distributed variable or parameter, indicators such as mean and variance can be identified which would allow confidence intervals to be placed around point estimates. In other words, instead of saying the benefit/cost (B/C) ratio for a project is 1.20, we might be able to say that we are 90 percent confident that the B/C ratio exceeds the value of 1.15, which gives the decision-makers more information to consider when evaluating projects.
- **Robust decision methods.** Robust decision methods are designed to help decision-makers identify solutions (or resource management strategies) that are robust across a wide range of plausible future conditions. These methods are particularly useful when uncertainties cannot easily be characterized using probability distributions. Many argue, for example, that we do not know enough about how the climate may change in response to greenhouse gas emissions and other natural changes, to assign

meaningful probabilities to individual climate scenarios. Robust Decision-Making (RDM) is a specific robust decision method that systematically identifies the key vulnerabilities of promising water management strategies and then guides the development of more robust options. Researchers with RAND Corporation and Penn State University are evaluating how RDM methods can used in conjunction with methods to optimize systems with multiple, complex objectives. This method, referred to as Many Objective Robust Decision Making, is described in the next section.

- **Stochastic simulation**. This is also known as Monte Carlo simulation or model sampling. An example of this type of analysis is the US Army Corps of Engineers' (USACE) software program, HEC-FDA (Flood Damage Assessment) that directly incorporates uncertainties into a flood damage analysis. For example, direct inputs into this program include frequency/discharge, stage/discharge, and structural inventories for which stage/damage curves are determined within the program. FDA statistically assigns error bands around all of these relationships, and then through a Monte Carlo analysis, samples within the various relationships' error bands in order to determine expected annual damage. Although this program is still subject to the same fundamental sources of uncertainty (model specification and data collection/measurement), at least it explicitly attempts to incorporate uncertainty into the flood damage analysis.
- **Game theory** (excerpt from http://en.wikipedia.org/wiki/Game_theory). Game theory is a study of strategic decision making. Specifically, it is the study of mathematical models of conflict and cooperation between intelligent rational decision-makers. An alternative term suggested "as a more descriptive name for the discipline" is interactive decision theory. Game theory is mainly used in economics, political science, and psychology, as well as logic and biology. The subject first addressed zero-sum games, such that one person's gains exactly equal net losses of the other participant(s). Today, however, game theory applies to a wide range of behavioral relations, and has developed into an umbrella term for the logical side of decision science, including both humans and non-humans (e.g. computers).

Risk Assessment Examples

Risk assessments provide a way to quantitatively consider the uncertainties that relate to events of interest. DWR and others are beginning to conduct more risk assessments as part of planning for the future. The Water Plan encourages all resource planners to incorporate risk assessments into their planning for integrated regional water management, which includes integrated flood management. This provides the basis for balancing risks with rewards in planning for more sustainable outcomes. Some examples of ongoing projects that include risk assessments are given here.

Central Valley Flood Protection Plan. On June 29, 2012 the Central Valley Flood Protection Board unanimously adopted the Central Valley Flood Protection Plan (CVFPP), a comprehensive new framework for systemwide flood management and flood risk reduction in California's Central Valley encompassing the Sacramento and San Joaquin River Basins (CA DWR 2012). The CVFPP provides conceptual guidance to reduce the risk of flooding for about one million people and $70 billion in infrastructure, homes and businesses with the goal of providing 200-year (1 chance in 200 of flooding in any year) protection to urban areas and reducing flood risks to small communities and rural agricultural lands. The CVFPP proposes a systemwide investment approach for sustainable, integrated flood management in areas currently protected by facilities of the State Plan of Flood Control. The CVFPP will be updated every five years, with each update providing support for subsequent policy, program, and project implementation.

California's Flood Future: Recommendations for Managing California's Flood Risk. DWR and the U.S. Army Corps of Engineers conducted the first characterization of statewide flood risk, along with the challenges, opportunities, and recommendations for improving and financing flood management as part of integrated water management activities. The California Flood Future Report explores financing, institutional, legislative and policy options available to help improve local and regional flood management systems. The Final Flood Future Report was issued in November 2013 (CA DWR 2013). See http://www.water.ca.gov/sfmp/ for additional information about the California Flood Future Report.

Delta Risk Management Strategy. The Delta Risk Management Strategy (DRMS) completed a study evaluating risks from levee failures in the Delta and ways to reduce those risks (URS 2011). DRMS provides a framework for evaluating major threats to the Delta levee system and the impacts that levee failure can have on the Delta ecosystem and economy, the State's water delivery system and other infrastructure, and those who rely on the exports of fresh water from the Delta. The DRMS assessment provides preliminary estimates of the probability that multiple islands will flood simultaneously during a 25-year exposure period due to a seismic event as shown in Figure 1. For example, there is a 40 percent probability of a major earthquake causing 27 or more islands to flood at the same time in the 25-year period from 2005 to 2030. DRMS estimated that if 20 islands were flooded as a result of a major earthquake, the export of fresh water from the Delta could be interrupted for about a year and a half. Water supply losses of up to 8 million acre-feet would be incurred by State and federal water contractors and local water districts.

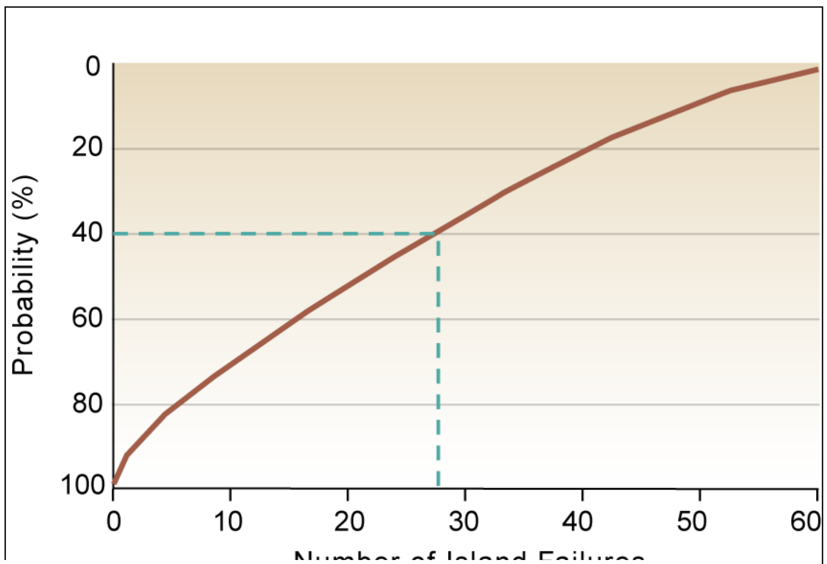


Figure 1. Probability of a Number of Simultaneous Levee Failures from a Seismic Event During a 25-year Exposure Period (2005-2030).

For more information on DRMS, visit the website at www.drms.water.ca.gov/.

California Statewide Levee Database. California has more than 13,000 miles of levees that protect residential and agricultural lands. The levee failures in New Orleans during hurricane Katrina prompted DWR to initiate development of a state-of-the-art levee database for the purpose of better understanding and managing levees. The California Levee Database (CLD) will support an efficient and effective approach for assessing levee reliability, risk assessment factors, and structural data impacting individual levee reaches. Currently, the California Levee Database has location information for more than 10,000 miles of levees and flood control structures throughout California. The CLD is being coordinated with a similar nationwide database being developed by the USACE.

DWR Economic Analysis for Flood Risk Management. DWR has prepared its Economic Analysis Guidebook (DWR 2008 www.water.ca.gov/economics/guidance.cfm) to set forth procedures for consistent economic analysis by DWR for the large list of flood risk reduction studies and projects that are under way or will be started over the next several years. These include major analyses for the Central Valley Flood Protection Plan, the State Plan of Flood Control, regional flood management planning, and various grant programs. DWR has a policy that, with the exception of the economic discount rate used, economic analyses conducted for its internal use on programs and projects should be consistent with the National Economic Development and Regional Economic Development analysis approaches used in the federal Economics and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G). The P&G procedures are technically sound and using them facilitates coordination with the considerable water management partnerships DWR has with the federal government. Adopted by the US Water Resources Council on March 10, 1983, the P&G was updated in March of 2013.

The updated P&G include broad principles to guide water investments, as well as draft Interagency Guidelines for implementing the Principles & Requirements. Developed by Federal agencies and incorporating extensive public comment, the modernized P&G will help accelerate project approvals, reduce costs, and support water infrastructure projects with the greatest economic and community benefits. They will also allow agencies to better consider the full range of long-term economic benefits of protecting communities against future flood damage, promoting recreational opportunities that fuel local business, and supporting other locally driven priorities (See http://www.whitehouse.gov/administration/eop/ceq/initiatives/PandG). In addition, The USACE requires that risk analysis be conducted for all of its flood damage reduction studies. For agencies seeking USACE funding and/or levee certification, approved risk analyses must be applied. USACE guidance on risk analysis can be found in:

- EM 1110-2-1619, Risk-Based Analysis for Flood Damage Reduction Studies, August 1996 and
- ER 1105-2-101, Risk Analysis for Flood Damage Reduction Studies, January 2006

Least-Cost Planning Simulation Model. DWR developed the Least-Cost Planning Simulation Model (LCPSIM) to evaluate risks of water supply shortages. It is a yearly time-step simulation/optimization model that assesses the economic benefits and costs of enhancing urban water service reliability at a regional level (www.water.ca.gov/economics/models.cfm). The LCPSIM output includes the economically efficient level of adoption of reliability enhancement measures by type, including the cost of those measures. The LCPSIM accounts for the ability of shortage event management (contingency) measures, including water transfers, to mitigate regional costs and losses associated with shortage events as well as the ability of long-run demand reduction and supply augmentation measures to reduce the frequency, magnitude, and duration of those shortage events. Forgone use is the difference between the quantity of water demanded and the supply available for use.

Presenting Uncertainty About Climate Change to Water-Resource Managers. This report documents a series of three workshops conducted by RAND with the Inland Empire Utilities Agency (IEUA) in Southern California in fall 2006 (Groves et al., 2008 and Lempert and Groves 2010). The workshops were supported by modeling to explore how different descriptions of uncertainty about the effects of climate change and other key factors on IEUA's projected supply and demand might influence water managers' perceptions of risk and preferences for new infrastructure investments, changes in operational policies, and adoption of regulatory measures. RAND used Robust Decision Making (RDM) analysis for decision support when conditions present deep uncertainty. RDM uses computational methods to identify vulnerabilities embedded in a long-term resource-management plan.

The report presents a decision analysis of potential IEUA-region water-planning responses using three different formulations of uncertainty: traditional scenarios; long-term, probabilistic forecasts; and policy-relevant scenarios through Robust Decision Making. Figure 2 shows the tradeoffs between reducing the identified vulnerabilities and the level of effort required to implement additional management actions. In the figure, circles indicate static strategies and diamonds indicate adaptive strategies. DYY refers to supply from the Metropolitan Water District of Southern California's dry-year-yield program.)

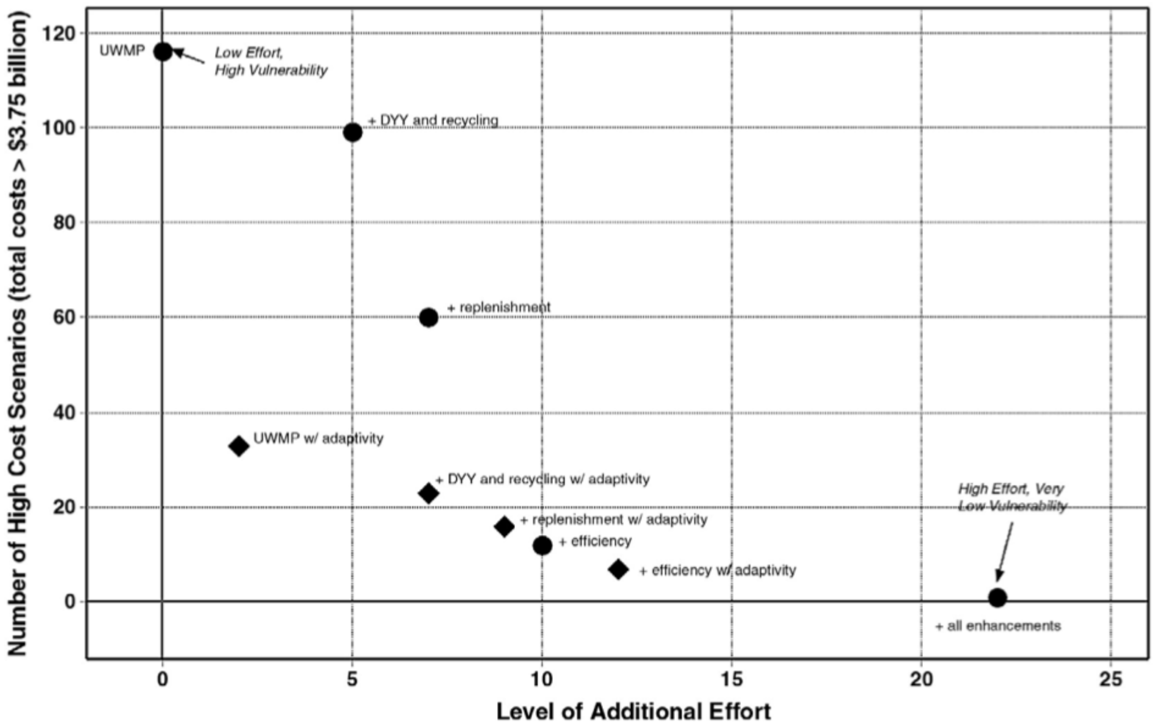


Figure 2. Tradeoffs between reducing vulnerabilities and effort on the part of IEUA and its partners and customers

Many Objective Robust Decision Making. Water resources planning has traditionally used historical data within benefit-maximizing frameworks for system design. The validity of this approach is threatened by environmental change and population growth, which create deep uncertainties that modify the distributions of data that characterize the system. Furthermore, solutions from the traditional benefit-maximizing approaches may prove inferior when multiple, complex objectives are introduced (e.g., maximizing reliable performance or environmental quality). Researchers with RAND Corporation and Penn State University are evaluating how RDM methods can used in conjunction with methods to optimize systems with multiple, complex objectives. This method, referred to as Many Objective Robust Decision Making (MORDM), was developed to solve such multiobjective problems under deep uncertainty by combining many-objective evolutionary algorithm (MOEA) optimization, robust decision making (RDM) and interactive visual analytics. MORDM was recently demonstrated using a risk-based water supply portfolio planning problem in the Lower Rio Grande Valley of Texas.

The framework, presented in Figure 3, begins with a Problem Formulation (XLRM): uncertainties beyond the decision maker's control (X); decision levers that can modify the system (L); measures (M) to quantify performance; and a relationship (R), generally a simulation model that maps the decision maker's actions to performance outcomes. The second step, Generating Alternatives, uses a MOEA to generate multiple planning alternatives or strategies, using a baseline state of the world (SOW) to calculate values for multiple output measures.

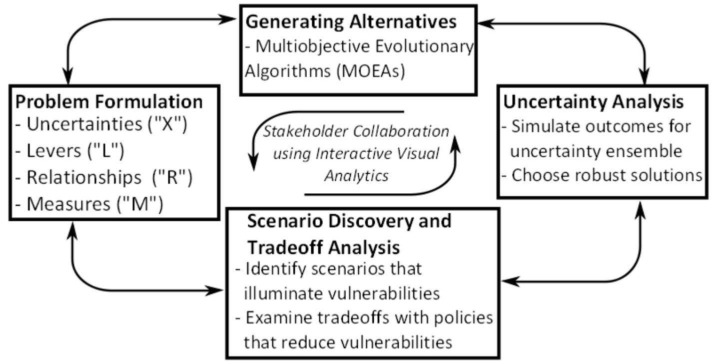
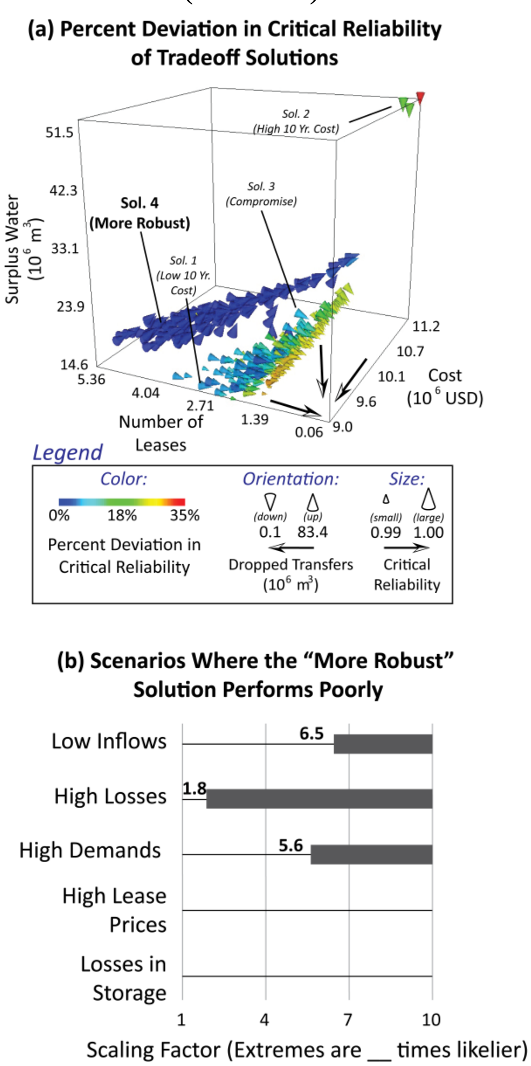


Figure 3. MORDM Framework

MORDM uses an a posteriori approach to decision support, with no weight or preferences defined in the beginning of the analysis. Presenting the full range of output measure values allows users to often discover surprising relationships between alternative solutions. For example, the spatial coordinates in Figure 4a show a contrast between high cost alternatives (solution 2) and solutions with higher numbers of leases that exhibit lower costs (solution 1).



After the tradeoffs are generated, Uncertainty Analysis globally samples deeply uncertain exogenous factors and evaluates the performance of each alternative in multiple SOWs. Color in Figure 4a shows each solution's percent deviation in a Critical Reliability measure compared to the measure in the baseline SOW. Solution 4 has very low deviation compared to Solutions 1-3, indicating robust performance across many SOW. Scenario Discovery and Tradeoff Analysis then uses statistical cluster analysis to provide simple, easy-to-understand descriptions of the combinations of deeply uncertain factors that cause the chosen robust solutions to perform poorly. Figure 4b shows an example in which high losses, low inflows, and high demands could cause performance vulnerabilities for the solution. The results motivate monitoring of system states and further adaptive planning to ameliorate these vulnerabilities. In summary, MORDM can help decision makers formulate problems, generate promising management alternatives, and evaluate the robustness of those alternatives in an uncertain future.

Figure 4. Example MORDM results. Fig. 4a uses coordinates, orientation, and size to show measure values in the baseline SOW. Color is an indicator of the change in critical reliability under the uncertainty ensemble. Figure 4b uses Scenario Discovery to discover ranges of uncertainty in which the solution performs poorly on a suite of reliability measures.

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